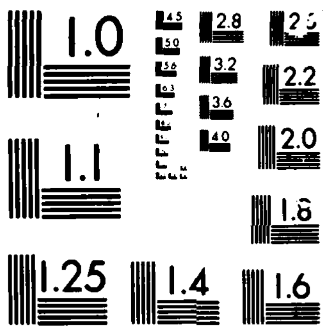
AD-A166 859 GEOGRAPHIC INFORMATION SYSTEMS IN ROBOTIC VEHICLES(U) 1/1
ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA
B B ZIMMERMAN ET AL. 1986 ETL-R-083

UNCLASSIFIED F/G 13/6 NL



MICROCOP' CHART

AD-A166 859

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ETL-R-083	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Geographic Information Systems in Robotic Vehicles	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Bruce B. Zimmerman, Richard L. Rosenthal and Jerry M. Breen	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Topographic Laboratories, Fort Belvoir, VA 22060-5546	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: same	12. REPORT DATE
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release.
Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC
ELECTE
APR 2 4 [illegible]
S D
D

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Robotic vehicles
Supervised Autonomy
stereo vision
route planning
three-dimensional maps

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Robotic vehicles offer potential to the Army for force multiplication and removing the soldier from hazardous environments. The Army robotic vehicle program will provide a supervised autonomy capability with full battlefield mobility. To accomplish this the control system will require a person in the control loop at least part of the time. The Army program incorporates several technologies including a digital terrain data base, product generation capabilities, stereo vision, and an inertial position and attitude unit. These technologies allow for vehicle

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

operation over-the-hill and beyond line-of-sight. This paper will discuss the detailed use of terrain data and terrain data products, such as route planning and three-dimensional synthetic scenes, in the interactive control of a robotic vehicle. Of particular importance is the relation of the terrain data to the vision data and position and attitude data. This paper will also discuss the similarities and differences between GIS requirements for interactive robotic vehicle control and autonomous vehicles, such as in the DARPA Autonomous Land Vehicle program.

GEOGRAPHIC INFORMATION SYSTEMS IN ROBOTIC VEHICLES

by

Bruce B. Zimmerman, Richard L. Rosenthal and Jerry M. Breen

U.S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060-5546

ABSTRACT

Robotic vehicles offer potential to the Army for force multiplication and removing the soldier from hazardous environments. The Army robotic vehicle program will provide a supervised autonomy capability with full battlefield mobility. To accomplish this the control system will require a person in the control loop at least part of the time. The Army program incorporates several technologies including a digital terrain data base, product generation capabilities, stereo vision, and an inertial position and attitude unit. These technologies allow for vehicle operation over-the-hill and beyond line-of-sight. This paper will discuss the detailed use of terrain data and terrain data products, such as route planning and three-dimensional synthetic scenes, in the interactive control of a robotic vehicle. Of particular importance is the relation of the terrain data to the vision data and position and attitude data. This paper will also discuss the similarities and differences between GIS requirements for interactive robotic vehicle control and autonomous vehicles, such as in the DARPA Autonomous Land Vehicle program.

INTRODUCTION

Army robotics programs officially began in 1981 when the Office of the Deputy Chief of Staff for Research, Development and Acquisition (DCSRDA) in Headquarters, Department of the Army formed an artificial intelligence (AI)/Robotics Steering Committee. This committee commissioned a survey of the Army User and Development communities on the use of this new technology called AI/Robotics which resulted in a prioritized list of hundreds of potential applications. The results of this survey were briefed to the top levels of Army management, which endorsed the basic concepts but recommended focusing Army resources on a few selected application areas.

Following this guidance initial plans were drawn up in 1982 for several near-term demonstration systems with the potential for future growth. One of the initial proposals was for an unmanned vehicle capable of carrying various modular payloads configured for specific missions. These could include battlefield reconnaissance, nuclear, biological, chemical (NBC) detection, weapons modules, target designators, etc. There was a desire to develop a fully autonomous system, at least as far as mobility is concerned, to minimize manpower and communications requirements.

However, technological reality dictated that true autonomy was decades away so the plans called for a teleoperated control system to provide a near-term military capability. While the system would require a person to be in the control loop full time, the primary goals of vehicle robotics could be accomplished: 1) to remove the soldier from potentially hazardous environments; and 2) to provide for force multiplication by being able to field a higher ratio of vehicles to crew size than is possible today.

In addition the initial plans called for incorporation of key technologies to allow for over the hill, non visual-line-of-sight control and for evolutionary growth toward autonomy; i.e., to gradually reduce the amount of time the person is required in the control loop. Among these critical technologies are the use of digital terrain data bases and derived products in conjunction with stereo vision and an inertial measurement unit.

This paper will describe both interactive and autonomous robotic vehicle control systems and the role that terrain data bases and products derived from the terrain data bases play. These products rely on the use of geographic information systems (GIS) and by way of example the use of GIS in robotic vehicles will be illustrated.

ROBOTICS BACKGROUND

The basic plans for the robotic vehicle program have undergone significant evolution since the formative years of 1982 through 1984. The program is now called the Supervised Autonomy Testbed (SAT) and is under the direction of an interlaboratory management team. The Army's vehicle developer, the Tank-Automotive Command (TACOM) is the lead lab and the Engineer Topographic Laboratories (ETL) and the Human Engineering Laboratory (HEL) are the other two primary members.

Figure 1 shows an artist's conception of the vehicle system in operation. In the background is the unmanned platform equipped with remote actuators, an inertial unit, stereo cameras, and a reconnaissance module to accomplish mission objectives. In the foreground is the remotely located command and control station where the person driving the vehicle, and perhaps a second person monitoring the recon sensor display, are located. A stationary van will be used for demonstration purposes but any fielded system would place the command and control station in a mobile platform also. The computers, displays (graphic and stereo vision), and digital terrain data base are located in the command and control station. A non visual-line-of-sight communications system will provide the link between the unmanned platform and the command and control station to allow over the hill operation.

Figure 2 shows an artist's concept of the driver's station in the command and control center. The lower left display depicts a (digital) map of the area of operation, a preplanned optimal route derived from this a priori knowledge, and a blinking cursor overlay derived from the x, y, and heading data from the inertial unit. The two upper displays, which are intended to convey the idea of a stereo vision display, provide the primary sensory input for driving the vehicle. The blinking cursor display resorts to a

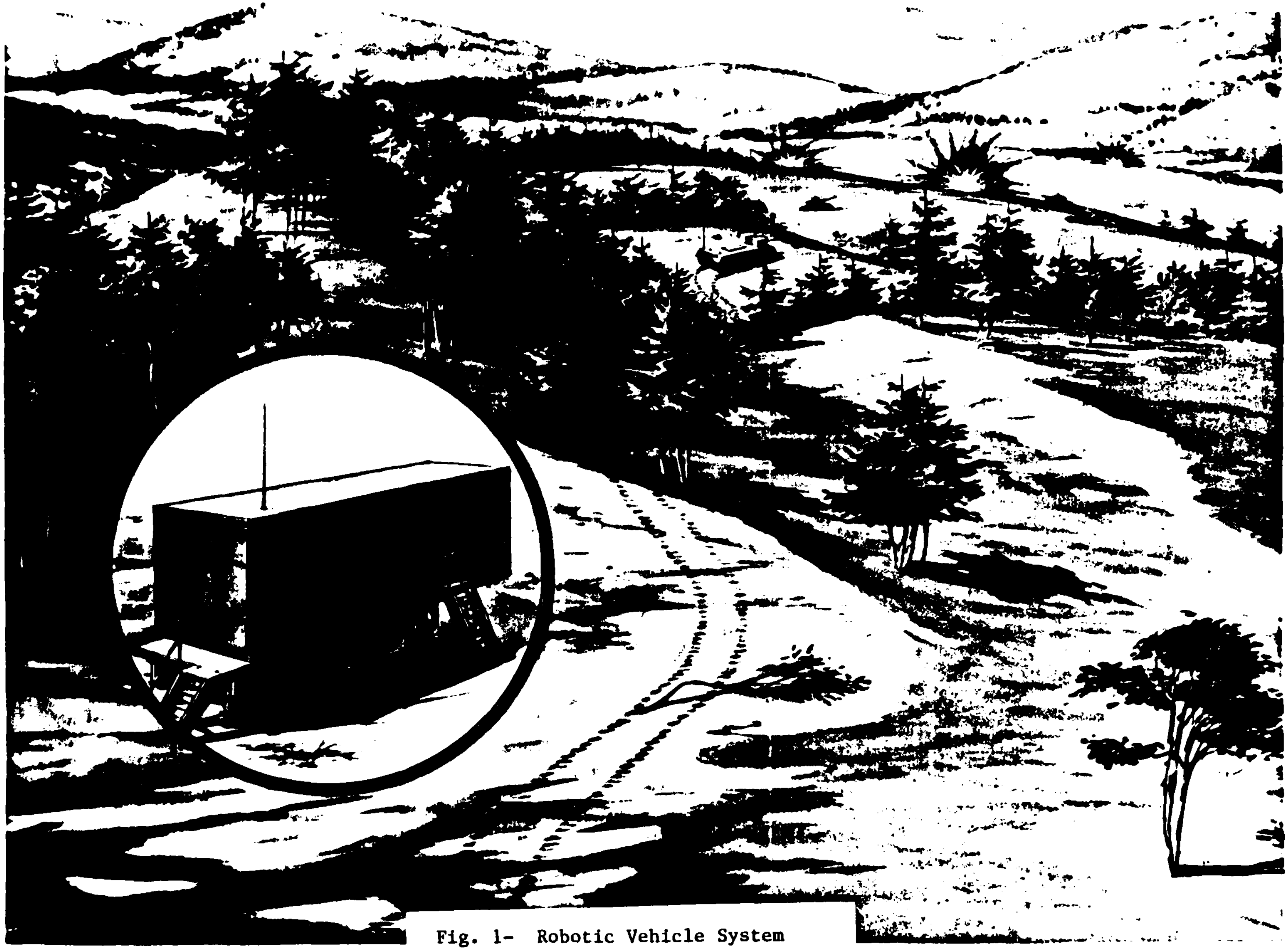


Fig. 1- Robotic Vehicle System

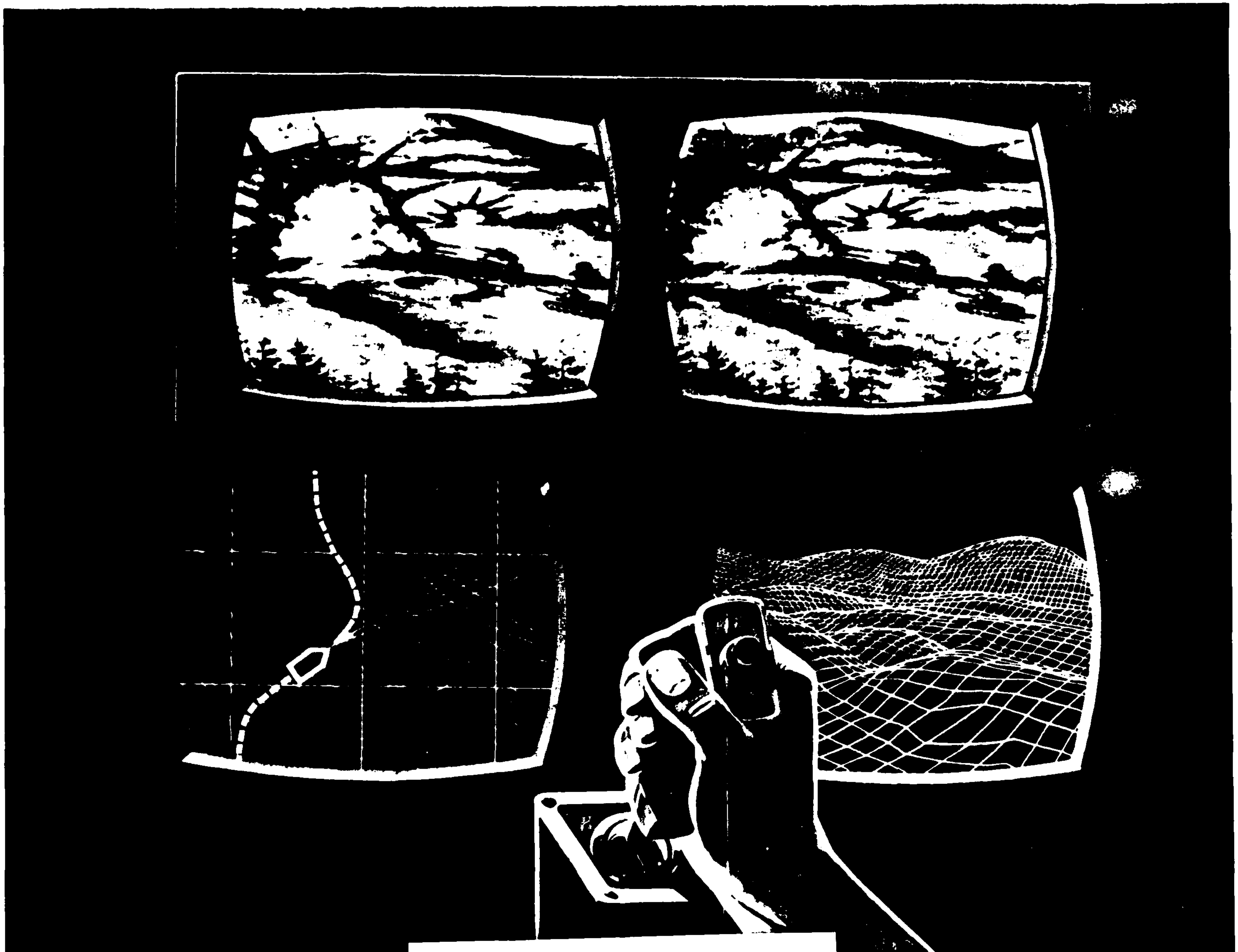


Fig. 2- Vehicle Operator Station

navigation aid after premission planning has been accomplished. The final display, in the lower right corner, is a simplistic rendition of what the terrain along critical portions of the route might look like to the driver.

In this person-in-the-control-loop scenario the human is either performing or supervising decision making processes such as approving the preplanned route, interpreting the stereo vision, detecting obstacles and planning local path maneuvering around the obstacles, performing landmark recognition, maintaining mission progress in the context of the preplanned route, and even replanning the global route when the situation warrants. If the person makes all of these decisions then the system is pure teleoperation. If the computer is able to make some of the decisions but able to call on the human for help when needed, then the system is exercising supervised autonomous control.

If a machine can be made intelligent enough to peform all, or substantially all of the decision making, then the system would be termed autonomous. Today's technology, and perhaps even tomorrow's, does not provide the machine intelligence to autonomously maneuver through the complex, unstructured environment of battlefield terrain. However the Defense Advanced Research Projects Agency (DARPA) is tackling this high risk, but potentially high payoff problem with their Autonomous Land Vehicle (ALV) program, figure 3. ETL is the DARPA agent for this program which provides a focus for the comprehensive research being conducted in the Strategic Computing Program of which the ALV is an integral part. The ALV achieves autonomy in the near-term at the expense of mobility; the ALV is currently capable of traversing only obstacle free roads at relatively low speeds. However, just as the Army's SAT program will evolve greater autonomy over time, the ALV will evolve greater maneuverability over time. In 1986 the ALV will be capable of navigating roads with obstacles, in 1987 desert type of off road terrain, and eventually more complex terrain at higher speeds.

The ALV incorporates digital terrain data bases, vision systems, and an inertial unit just as the SAT does. In the case of the ALV the machine interprets the data and automatically makes decisions while in the SAT a combination of human and machine processing is used. The SAT is designed as the Service program to directly incorporate the DARPA research results, and the ALV will serve as the primary source of the technologies that will enable the SAT to achieve greater autonomy over time. The SAT program offers a continually evolving military capability in robotic vehicles as it always retains full terrain mobility, while the ALV program seeks yearly breakthroughs in the state-of-the-art in autonomous systems.

The principles of supervised autonomy control are currently under development in the Army Advanced Ground Vehicle Technology (AGVT) program, which is a precursor to the SAT program. Both FMC Corporation and General Dynamics, under contract, are modifying their IR&D robotic vehicle systems to incorporate today's ALV road following algorithms. During the summer of 1986 the first demonstration of a supervised autonomy control of a military vehicle will be conducted at the ALV test site. The vehicles will perform a route reconnaissance mission scenario which will allow teleoperation over cross

Fig. 3- Autonomous Land Vehicle

country terrain and autonomous road following on paved road surfaces using the ALV algorithms.

The fact that both of these robotic vehicle systems make use of digital terrain data bases, and products derived from these data bases, is the basis for this paper. GIS principles are deeply imbedded in the operation of supervised or fully autonomous control systems for robotic vehicles. While GIS principles are much more implicit than explicit in robotic vehicles, their efficient and functional operation is crucial to successful military missions. What follows is a discussion of the products and procedures used in robotic vehicle operations that are dependent on GIS principles.

TERRAIN DATABASES IN ROBOTIC VEHICLE CONTROL SYSTEMS

Terrain analysis data in digital form provide a priori knowledge of the natural and cultural features in an operational area of a robotic vehicle. Additional data in digital form derived from sensors and intelligence data supplement the terrain analysis data. These data provide a basis for automating several aspects of control systems for robotic vehicles including route planning and graphic displays.

Whether or not a vehicle is deployed in a teleoperated or supervised autonomous mode, its ability to perform its mission depends on effective navigation to achieve a task goal. The navigation process considers both local path planning functions and global route planning.

Automated route planning involves the use of digital terrain analysis data with knowledge of troops or vehicles to establish a route to travel between locations. Route planning must also consider multiple goals, constraints, and temporal factors. Route planning can involve replanning in the event new knowledge invalidates the route being followed.

ETL has developed a route planner development workstation which serves as a laboratory research tool to support the development, understanding, evaluation, and testing of automatic route planning algorithms for land based robotic vehicle applications. The workstation provides a structured and efficient working environment for developing algorithms. The workstation technology has potential for incorporation in fielded applications. The hardware for the route planner development workstation consists of a Lisp machine with color graphics display terminal. The Lisp machine provides a powerful symbolic processing capability and is widely used for artificial intelligence applications.

The commander of a robotic vehicle must be able to visualize the terrain within his area of responsibility to effectively operate within it. The basic planning tool in use today by the Army is the large-scale topographic map. The commander must be able to translate the map's symbology into the reality of the Earth's land form. This realization of the form of the terrain on a rapidly developing battlefield must be timely and accurate. Ideally, the map user should be able to visualize the terrain's three-dimensional

characteristics by merely studying the map's contour lines. Unfortunately, considerable training, experience and time are required to interpret exactly what the relief is like as depicted by the map's contour lines.

The map sheet is not effective for use as an analytical tool for such operations as determining line-of-sight between terrain points. Analytical operations involving terrain data are common in the field as when a commander plans optimal positions for observation or concealment. Automated systems incorporating digital terrain analysis data with appropriate algorithms can provide the commander of a robotic vehicle with three-dimensional perspective maps. The 3-dimensional perspective map, such as shown in figure 4, presents a view of geographic information in a form which can be comprehended faster than the traditional 2-dimensional map.

ETL is demonstrating the potential for use of three-dimensional perspective maps for use in control systems for robotic vehicles through the development of a laboratory system consisting of a high-performance workstation for display of 3-D graphics and associated software. The workstation accepts as input digital gridded elevation data which has been converted to polygon form and associated digital planimetry. The digital data is the basis for the hardware bas creation of a 3-D perspective map. The sophisticated nature of the graphics hardware permits continuous graphic manipulation of the data.

Once loaded into the graphics workstation, geographic data can be displayed in 3-D using perspective or oblique views. A special case of the oblique looks at the terrain surface from directly above giving the appearance of standard softcopy 2-D maps. By interactively changing the viewing parameters of the graphics workstation, the viewing position can be changed to give a 3-D view.

The maps displayed on the 3-D graphics workstation provide the commander with an additional input with which he can make his own expert decisions with respect to operation of the robotic vehicle. The commander can use the interactive 3-D map to generally view and scroll through the geographic area of operation. The perspective and oblique views of the terrain provide an additional means for the commander to select end points for automated route planning operations and look for potential choke points and critical points. The results of automated route planning operations can be displayed on the 3-D display so that the commander can decide as to the effectiveness of the route. After a route has been selected, the commander can preview the route as it would be seen from the robotic vehicle through surrogate travel. While the robotic vehicle is actually traversing an area, the 3-D display can create graphic views which correspond with the views being transmitted by the video channel. Unlike the live video, the 3-D views can be made to show the predicted view ahead of the vehicle.

In either type of robotic vehicle control schema, supervised or autonomous, the terrain data can be used as a priori knowledge for interpreting the vision imagery for obstacle detection and avoidance. Today's technology has not solved the computer vision problem, which is one of the primary limitations to providing a full autonomous vehicle capability. The terrain data can

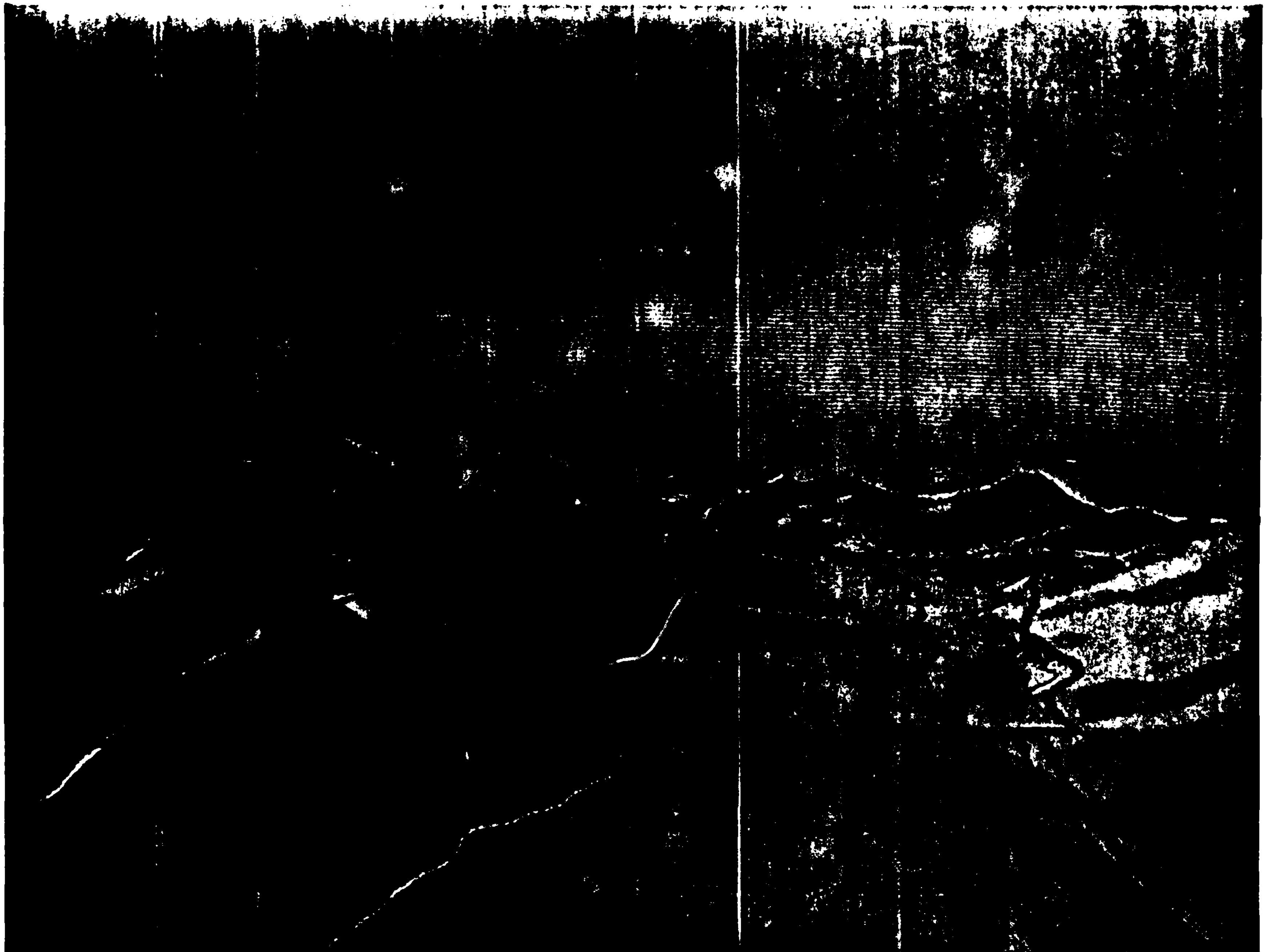


Fig. 4- Three-Dimensional Terrain Scene

be used to assist the machine by creating a machine readable predicted view of the terrain that can be correlated in some manner with the actual image view that is to be processed. Knowing where the preplanned route falls in the image can also be used to narrow down the portion of the image to be processed to only that section relevant to the vehicle path.

Many of the same functions that are performed in supervised vehicle control are performed in autonomous vehicle systems as well. The primary difference is that autonomous systems perform their operations with machine readable information that does not have to be put into human readable form. Autonomous systems require efficient access to terrain data for automatically planning a route or replanning a route when needed. In addition they also need to query the terrain data base for making decisions about preplanned routes.

As described earlier the terrain displays can be presented as a softcopy 2-D map. Using this as background information, the preplanned route can be overlayed over it. As the unmanned platform traverses the terrain the position and attitude information provided by the on-board inertial unit can be used to generate a blinking cursor overlay of actual vehicle position and heading to serve as a navigation aid. A history of vehicle movement can easily be added and the background map must be capable of being scrolled as the cursor nears the edge of the display.

In autonomous systems the terrain data provides the descriptive and geometric information to allow for landmark recognition and inertial system updates. While a human readable blinking cursor overlay would not be used, the machine must be capable of reasoning about the vehicle's position and movements.

SUMMARY

This introductory discussion of robotic vehicle operations that either explicitly or implicitly involve terrain analysis data bases, and the requisite geographic information systems, has hopefully illustrated the value of these types of data and products to military robotics systems.

The challenge to the robotics research community is not just how to best plan routes or generate the best quality graphics display, but rather how to best perform these operations within the physical and monetary limitations of robotic vehicle environments. In an autonomous system the entire computational capacity must reside on board the vehicle and in a supervised system the computational power is divided between the unmanned platform and the command and control center. In either case the speed, storage capacity, and cost of equipment provide a constraint against which researchers are trying to provide optimal geographic information systems capabilities.

Geographic information systems must be capable of scrolling through high resolution terrain data bases and providing the information in an optimal data structure for automatic route planning algorithms. Conventional conceptions of fixed size maps or geographical units, such as one degree squares, have to be abandoned in favor of one contiguous area of operation instantly available to a machine. The GIS must be capable of efficient

Paper title below this line

updating as new terrain knowledge is gained as the vehicle traverses the terrain. Tactical intelligence and environmental data have to be readily combined with the terrain data to most accurately portray the area of operation.

Given that these goals can be accomplished then geographic information systems will prove a most valuable tool in the pursuit of robotic vehicles to aid the soldier in the field.

END
FILMED

5-86

DTIC